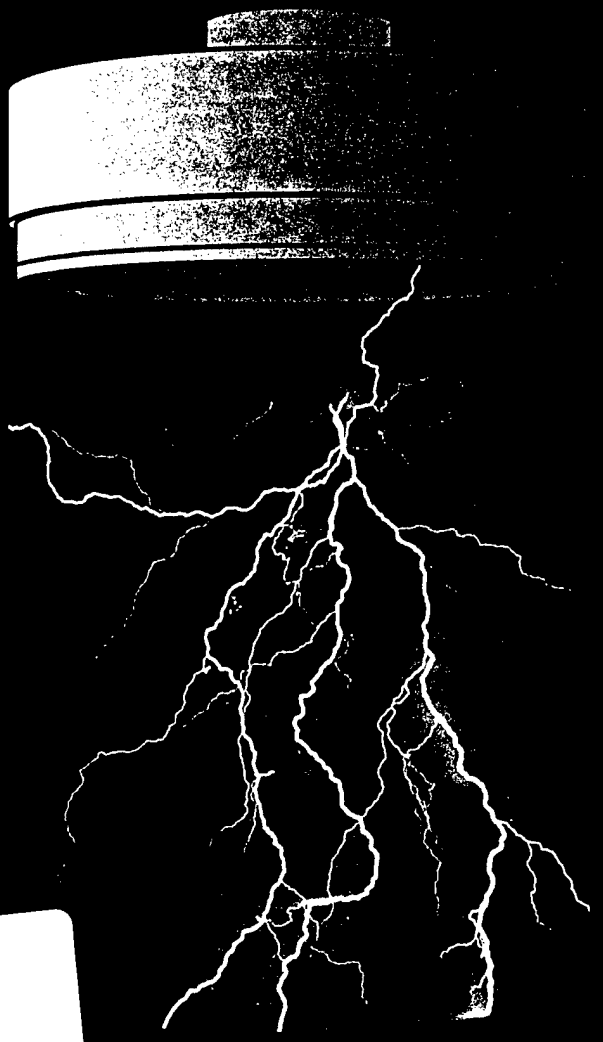
SMES

SUPERCONDUCTING MAGNETIC ENERGY STORAGE

BMD
Ballistic
Missile
Defense

1993



AN INITIATIVE FOR ECONOMIC COMPETITIVENESS

The Ballistic Missile Defense Organization (BMDO) Office of Technology Applications adds a valuable dimension to our far-reaching research and development (R&D) efforts. Acknowledging that technology is the engine that drives global economic competitiveness, we at BMDO have designed a proactive program to help American businesses leverage Federal R&D. We believe that interaction between government and industry is essential to develop and produce matchless technology in the United States, and we are proud to be at the forefront of technology transfer to support the nation's goals for economic competitiveness.

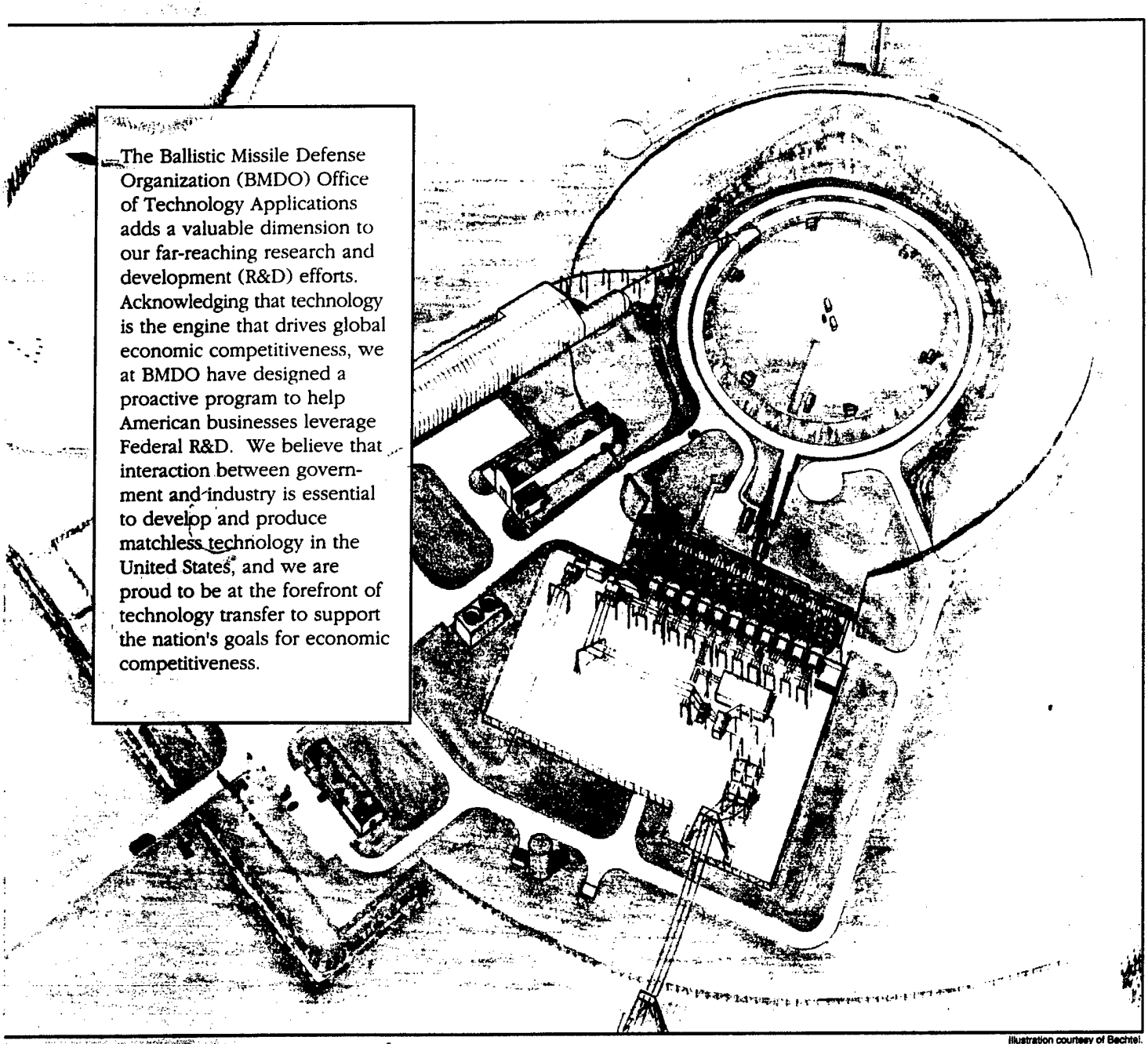


Illustration courtesy of Bechtel.

Schematic Illustration of Engineering Test Model, as proposed by Bechtel.

Front Cover Photograph
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Commercially Available ■ Internationally Competitive ■ Potential $40 Billion Market

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IN PURSUIT OF A POWERFUL TECHNOLOGY

The Ballistic Missile Defense Organization (BMDO), of the U.S. Department of Defense, needed a technology that could provide sudden bursts of energy for a ground-based laser. Superconducting Magnetic Energy Storage (SMES), a technology envisioned in 1969, showed many promises. With this technology, researchers could potentially use the concept of superconductivity as a basis to store energy — which later could efficiently supply very high power.

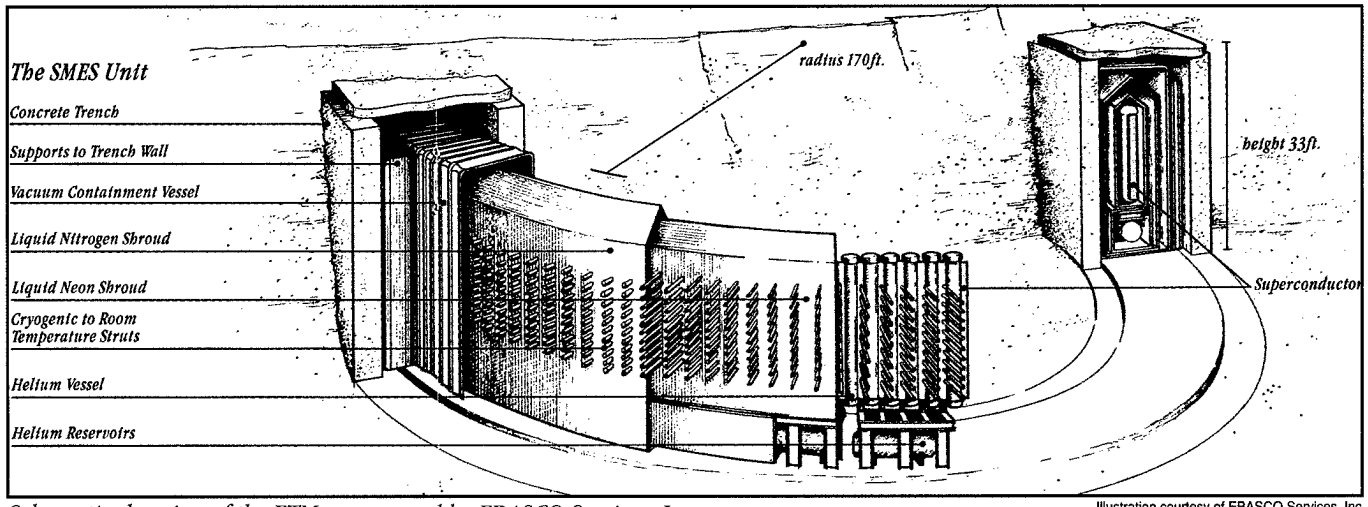
Therefore, in 1987, BMDO and the Electric Power Research Institute (EPRI) agreed to launch a 2-phased plan to develop a pilot plant — the Engineering Test Model (ETM). The ETM was based on previous research by the U. S. Department of Energy (DOE), Wisconsin utilities, Bonneville Power Administration, Bechtel, University of Wisconsin and EPRI. The design of the plant had to be big enough (20-megawatt-hours/400-megawatts) to demonstrate most of the features of a full-scale plant. This size plant would have a peak capacity of a small power plant and could provide this level of power for short periods of time.

BMDO funded much of the $30 million effort to develop and review two competing designs in the ETM program for Phase 1. Two contractor teams led by Bechtel and EBASCO Services, Inc. developed innovative designs, components, and materials over a 3-year period.

The Defense Nuclear Agency (DNA) and DOE have further researched military and utility applications, and in fiscal year 1994, large-scale research was transferred from DNA to the Navy.

BMD's investment in developing SMES includes contributions to:

- SMES design and component innovations, such as coil structure, conductors, and cyrogenic systems;
- Heightened awareness of SMES;
- Energy storage applications for utilities and industry;
- Creation of research opportunities in materials, biology, and superconductivity.



Schematic drawing of the ETM as proposed by EBASCO Services, Inc.

Illustration courtesy of EBASCO Services, Inc.

Cost Savings ■ High Performance ■ Enhanced National Security

WHAT'S IN STORE FOR:

- Utilities
- Industry and Transportation
- Military and Space
- Research . . .

Photo courtesy of U.S. Department of Energy.

Photo courtesy of U.S. Department of Energy.

Superconducting Magnetic Energy Storage is an electrical storage system that can potentially serve all of these communities.

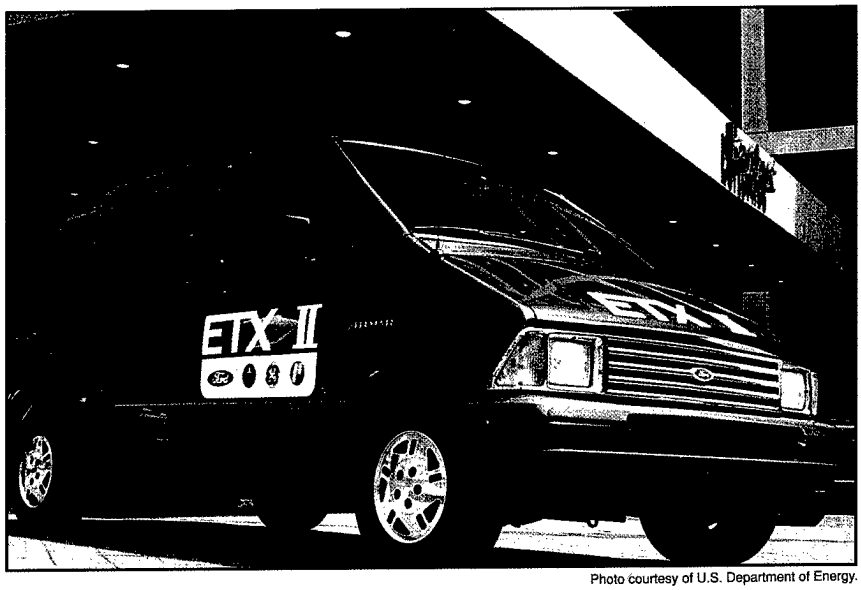
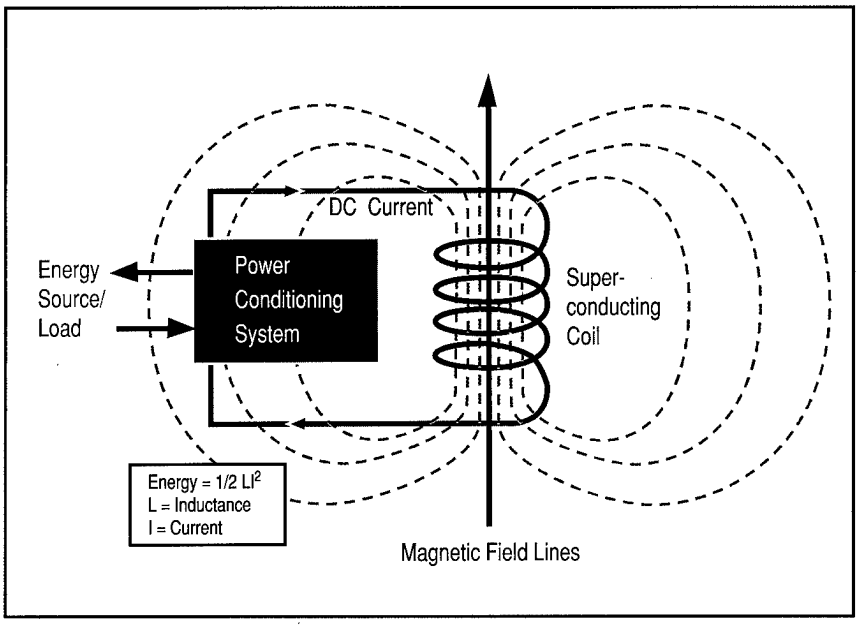


Photo courtesy of U.S. Department of Energy.

Commercially Available ■ Internationally Competitive ■ Cost Savings

WHAT IS SMES?



SMES is an innovative approach for storing energy that may offer utilities, industry, transportation, military, space, and research communities:

- Cost competitiveness,
- High efficiency,
- Reliability,
- Environmental improvements,
- Opportunities for small American businesses,
- Improved electric power quality,
- Research opportunities.

In SMES, energy is stored in a magnetic field that is produced by circulating current in a superconducting coil. The coil, which is charged and discharged through a solid-state power convertor, is kept at extremely cold (cryogenic) temperatures. The unique features of SMES allow for:

- Instantly available stored energy,
- High efficiency,
- Availability of pulse-mode capability,
- Unlimited cycle life.

Photo courtesy of General Atomics.

This 30 megajoule/10 megawatt experimental unit provided transmission stabilization for utilities on the west coast.

WHAT'S IN STORE FOR UTILITIES

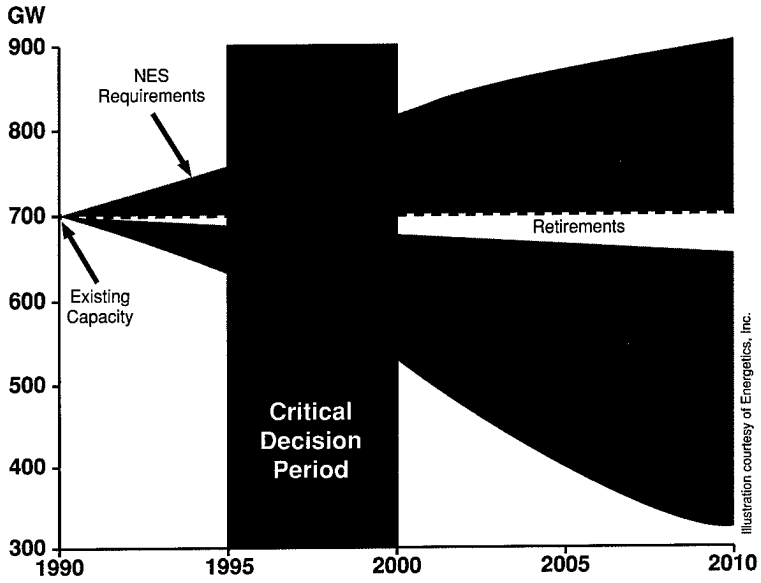
Displacing the Need for New Power Generation

Many utilities will need new electricity generation capacity within the next 5 to 15 years. With SMES, utilities can avoid building or upgrading power plants to meet peak power demands. SMES can help utilities meet the following needs:

- Low-cost power generation,
- Improved power plant efficiency,
- Reduced need for additional power generation during peak periods,
- Reduced wear and tear on existing power plants.

Now is the time to make utility planners aware of the potential of SMES as a solution for load leveling requirements, environmental compliance, and improved power quality needs.

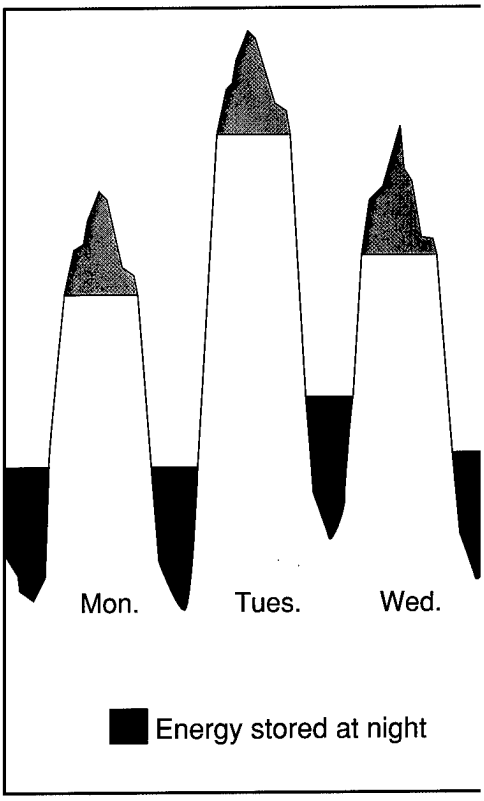
U. S. Electric Generating Capacity Trends (National Energy Strategy)



Load Leveling for Utilities

Most utilities do not store electricity. Stored electricity only accounts for about 3 percent of the electricity consumed in the United States. Therefore, generated electricity that is not used is usually wasted. SMES may allow utilities to store extra electricity produced off-peak (typically at night) and use it for on-peak — usually daytime — consumption. This is called load leveling.

Large-scale SMES used for electric utility load-leveling could supply up to 30 GW of the U.S. generation demand. Small businesses could make a valuable contribution to the potential $40 billion market created by SMES.



Environmental Benefits

SMES can potentially benefit the environment in many regions of the country. In many cases, SMES can potentially help utilities reduce or eliminate local or regional ambient air quality problems by fostering more flexibility when choosing power plants or systems. This flexibility may allow utilities to choose more efficient and less polluting strategies for producing power. SMES may also allow utilities to store electricity from inherently "clean" energy sources, such as solar or wind energy systems.

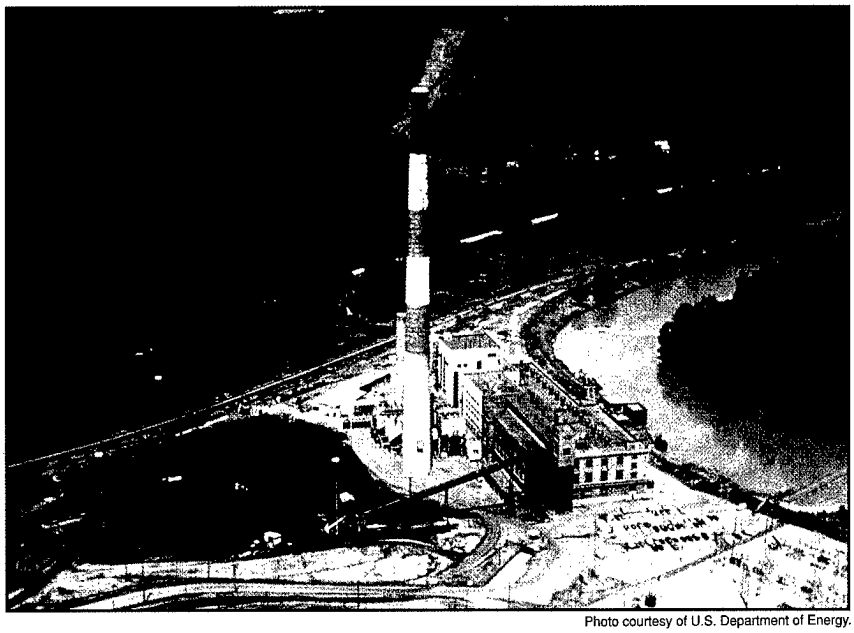


Photo courtesy of U.S. Department of Energy.

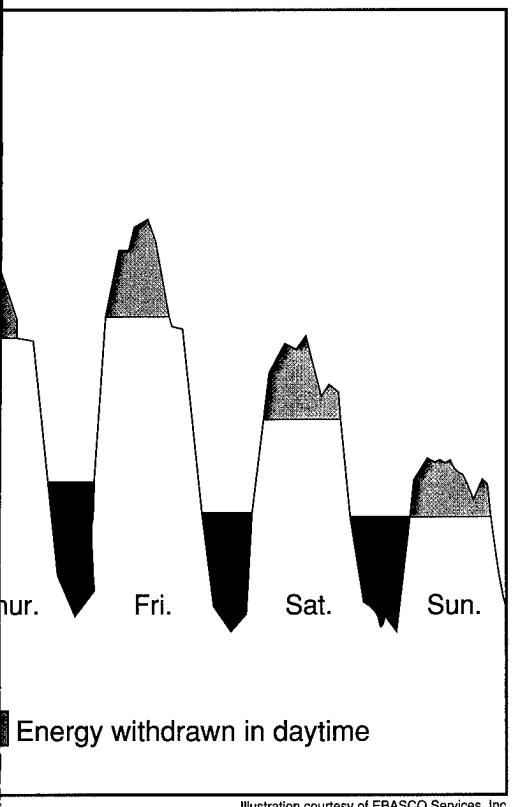


Illustration courtesy of EBASCO Services, Inc.

SMES can allow utilities to store electricity for load leveling.

Other Benefits and Potential Applications for Utilities

SMES offers a wide range of benefits for utilities in addition to load leveling and environmental advantages. SMES can potentially make a positive contribution to:

- Increased use of renewable energy,
- Electrical stability,
- Dynamic stability,
- Spinning reserve,
- Black start,
- Improved efficiency of transmission lines,
- Capacity reduction of transmission lines,
- Area protection/ transmission line deferral.

WHAT'S IN STORE FOR INDUSTRY AND TRANSPORTATION

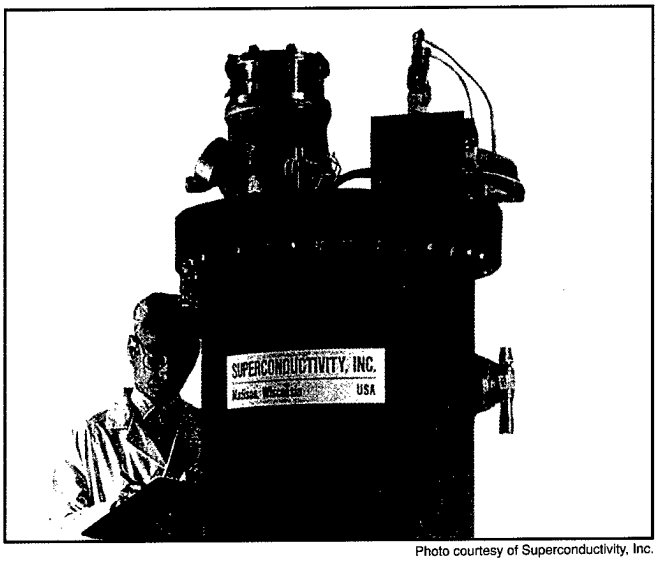


Photo courtesy of Superconductivity, Inc.

The SSD™ is commercially available SMES for industry.

Small-scale SMES for industrial applications is commercially available, with competition growing, both domestically and internationally.

Industrial Applications

With SMES, critical industries such as electronic manufacturing could potentially save billions of dollars each year in industrial processes and production, thereby improving global competitiveness.

In recent years, industrial process equipment has become more sophisticated and more sensitive to lapses in power quality on utility electric lines. Events such as lightning can cause momentary power outages or voltage sags on the incoming power lines to a factory or processing line. Interrupting critical procedures such as processing or testing semiconductor components can be very expensive and time-consuming.

SMES in small sizes can prevent these costly interruptions if installed at a customer facility or on the nearby distribution line. In fact, SMES has already been commercially developed to avoid such interruptions.

Transportation Applications

SMES offers several alternative modes for powering America's transportation system. Moderately small SMES systems can provide power for rapid transit systems and light rail — boosting voltage along the line and feeding motors as they accelerate. This technology can also provide power to magnetically levitated trains. A very small size SMES can potentially be part of a hybrid propulsion system on large transit buses. Conversely, a relatively large SMES system could recharge electric vehicles during the day, potentially eliminating the need for utilities to produce additional power during hours of peak demand to meet transportation needs.

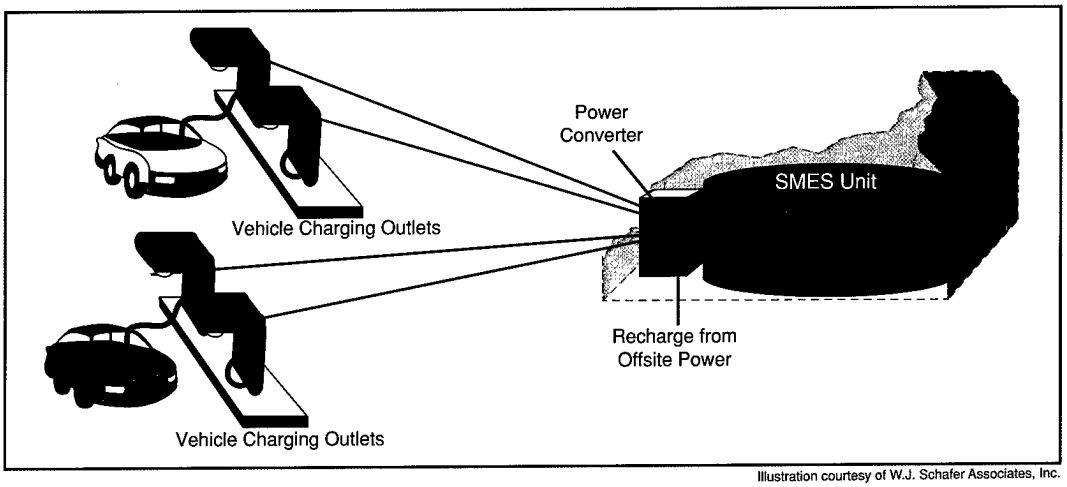


Illustration courtesy of W.J. Schafer Associates, Inc.

SMES can potentially lead to the increased use of urban transit, maglev and electric vehicles, thereby reducing air pollution.

Electric Vehicle Recharging Station.

WHAT'S IN STORE FOR MILITARY AND SPACE

Military Applications

SMES can potentially serve all forces of the military community for a wide spectrum of applications. For example, a very small SMES unit could supply needed power for on-board submarines and ships, while large-scale SMES projects could potentially provide power for ground-based weapon systems. Other potential applications for SMES include the following:

- Military base power,
- Military laboratory power,
- Naval applications,
- Air Force applications,
- Army field applications,
- Space applications.

Photo courtesy of the U.S. Air Force

SMES can potentially contribute tremendously to national security by offering a reliable power source. In addition to specific applications, SMES on the utility network can provide a secure, high-power source for critical military bases, weapons, and command and control centers in the event of a national emergency. SMES can also offer black start capability to the utility grid, which also plays a vital role in national security.

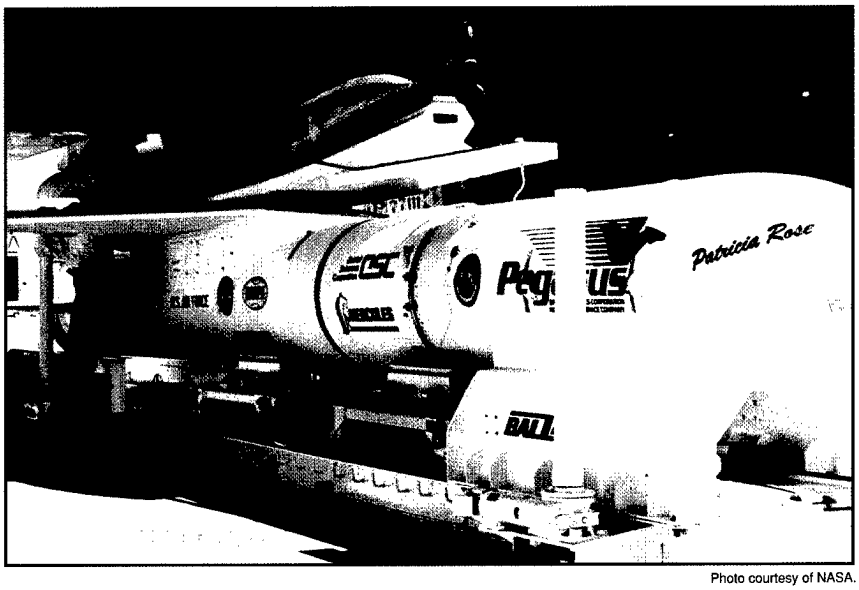


Photo courtesy of NASA.

NASA Applications

NASA has proposed numerous applications for superconducting components in future missions, including small-scale SMES for on-board satellite energy storage and large-scale SMES for storing energy on the surface of the moon. NASA also has projected that they will need power to launch small payloads into low earth orbit. A 100-MWh SMES unit would be ideal to provide electromagnetic launch power without disrupting the local electric grid.

National Security ■ Satellite Energy Storage ■ Launching Power

WHAT'S BEEN STORED FROM PREVIOUS RESEARCH

Research Discoveries

The first phase of the BMD-sponsored Engineering Test Model (ETM) program was undertaken to develop an advanced design concept of a large-scale SMES project. The program resulted in the many accomplishments related to a large-scale SMES design, such as the full-scale constructability mock-up of a coil section.

BMDO's perspective was that developing a suitable design for large-scale SMES was essential to provide the American public with a strong and active defense strategy; however, the success of the ETM program is measured not only by an outstanding SMES design, but also by its contribution — even on the component level — to other communities. Many of the advances in component design developed for large-scale SMES through ETM can be used for non-SMES-related applications.

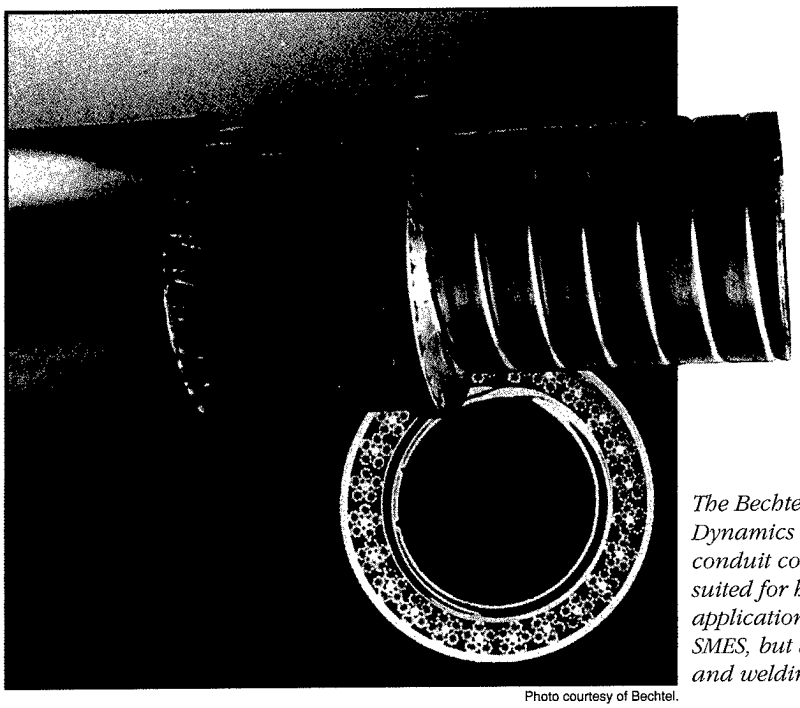


Photo courtesy of Bechtel.

The Bechtel/General Dynamics cable-in-conduit conductor is well suited for high current applications, not only in SMES, but also in fusion and welding applications.

Some of these innovations include advances in:

- Cable-in-conduit conductors;
- Aluminum-stabilized conductors;
- Composite materials;
- Innovative high-voltage insulation;
- Coil protection components, including valves, switches, and sensors;
- Vapor-cooled copper power leads;
- High temperature superconducting power leads.

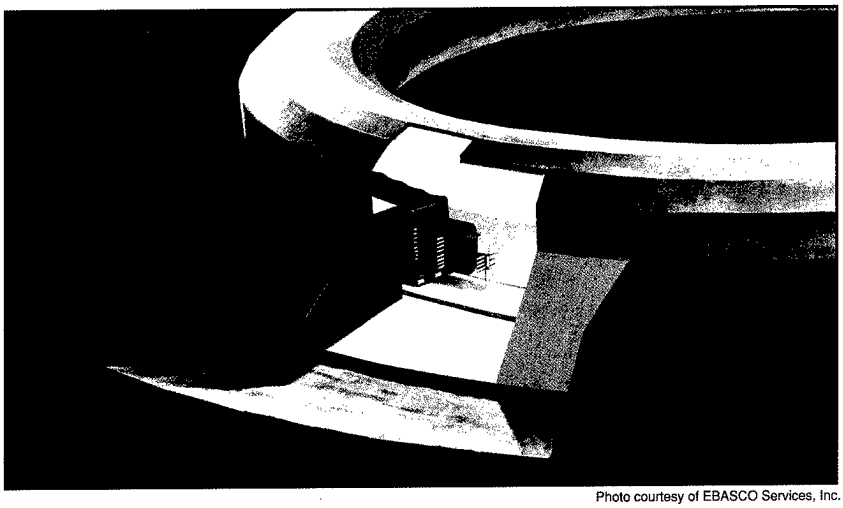


Photo courtesy of EBASCO Services, Inc.

The full section of the EBASCO coil shows all the structural connections of coil components in three dimensions.

WHAT'S IN STORE FOR FUTURE RESEARCH

National Research Facilities

The ETM also resulted in testing facilities which are available for other experiments. The proof-of-principle experiment (POPE) at the University of Wisconsin is part of the High Current Laboratory of the Applied Superconductivity Center. The Center holds state-of-the-art equipment for superconducting experiments.

The Texas Accelerator Center has also established facilities for testing high current conductors, up to a current of 300 kA. The facility uses an innovative superconducting transformer developed under the first phase of BMD support.

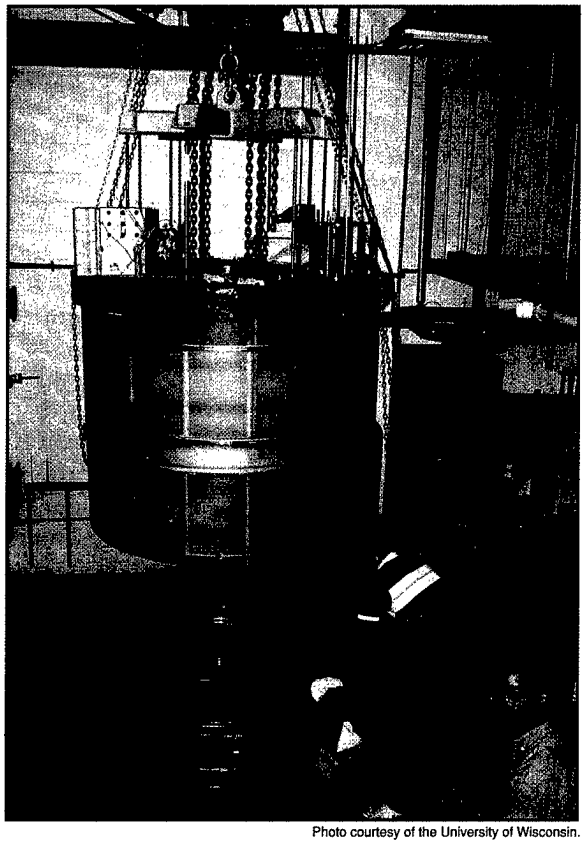


Photo courtesy of the University of Wisconsin.

The POPE at the University of Wisconsin

Related Research

Today's SMES designs use conventional metallic superconductors; however, there is great opportunity to use higher temperature ceramic superconductors, especially in the current leads that connect the cold coil to the warm power convertor. This application would save on refrigeration energy, especially for small SMES units. Development of high temperature leads has been spurred by SMES R&D.

Other research in materials, electronics, and especially biology may be possible with SMES. The magnetic field produced by the coil is a controllable dc field; it presents a unique opportunity for biological research.

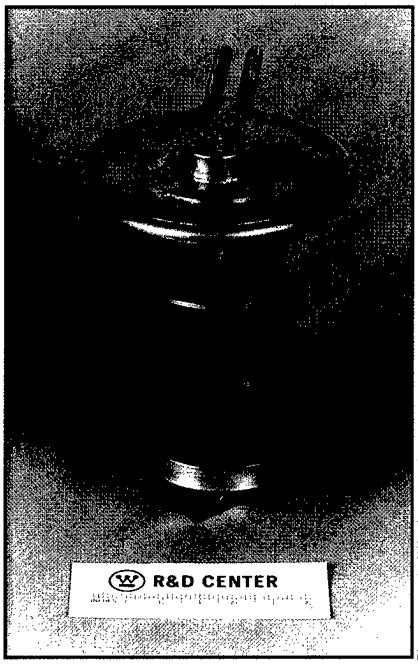


Photo courtesy of Westinghouse Service & Technology Center and Argonne National Laboratory.

High temperature superconducting coil leads.

For Further Information

The Office of Technology Applications has produced a detailed technical report on SMES called the "Superconducting Magnetic Energy Storage Technology Applications Analysis." This report, as well as other information on other BMD-funded projects with spinoff potential, can be obtained by calling or writing BMDO at the following location:

Office of Technology Applications
Ballistic Missile Defense Organization
The Pentagon
Washington, D.C. 20301-7100
(703) 693-1563